SAND2006-5556C, Paper # 116
presented at the 47th Annual Meeting of the INMM
Institute of Nuclear Materials Management, July 2006,
Nashville, TN

Spent Fuel Sabotage Test Program, Surrogate and Fission Product Aerosol Results

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ABSTRACT

We provide an overview and summarization of recent results from a multinational, spent fuel sabotage aerosol test program. This research study is quantifying aerosol particles produced when the products of a high energy density device (HEDD) interact with and explosively particulate test rodlets containing pellets of either surrogate or actual spent fuel materials, all within a contained test chamber. Results from this multi-year program provide needed source term data that are relevant to plausible sabotage attack scenarios on spent fuel transport and storage casks. A prime program objective is to support Department of Energy (DOE) assessments for physical protection requirements of nuclear materials in use, storage, and transport. Similarly, the Nuclear Regulatory Commission (NRC) needs the resultant aerosol source-term data and supporting analyses for a defensible validation of vulnerability studies associated with spent nuclear fuels. Testing results and design are tailored to support follow-on computer modeling of aerosol dispersal hazards and radiological consequence assessments. We summarize some of the significant findings on aerosol results and observations from the recently completed Phase 2 surrogate material tests using cerium oxide ceramic pellets in test rodlets plus non-radioactive fission product dopants. Results include: respirable fractions produced; particle size distributions and morphology; determination of the Spent Fuel Ratio (SFR), the ratio of respirable particles from real spent fuel/respirables from surrogate spent fuel); and, measurements of enhanced volatile fission product species sorption onto respirable particles. We discuss progress and results for the recently initiated Phase 3 tests using depleted uranium oxide, DUO_2, test rodlets. We will also review the status of preparations and the final Phase 4 tests in this program, using short rodlets containing actual spent fuel from U.S. PWR reactors, with both high- and lower-burnup fuel. This test program, performed primarily at Sandia National Laboratories, with support provided by both the U.S. DOE and the NRC, had significant inputs from, and is strongly supported and coordinated by both the U.S. and international program participants in Germany, France, and the U.K., as part of the International Working Group for Sabotage Concerns of Transport and Storage Casks (WGSTSC).

INTRODUCTION

This report provides a detailed summary of, and significant results from an ongoing, multinational test program that is measuring aerosol particle data for a spent fuel sabotage scenario relevant to spent fuel transport and storage casks. The casks used for spent nuclear fuel transport are extremely resistant to releasing any significant fraction of their contents, even in very severe accident conditions. However, in some credible sabotage scenarios, such as an attack employing high energy density devices (HEDDs), i.e., explosive armor-piercing weapons, it is possible that a small percentage of aerosolized particles from disrupted fuel pellet materials could be released. If released to the environment in a significant quantity, the spent fuel respirable particles have the

* Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94-AL85000.

potential to cause radiological consequences. Measurement of the actual amounts, nuclide content and size distribution of the released materials from spent fuel is essential for predicting the significance of the radiological impacts. These source-term data are the input for follow-on modeling studies to quantify respirable hazards, associated radiological risk assessments, vulnerability assessments, and potential cask physical protection design modifications. The need for accurately quantifying this information has been strongly supported by program participants in the U.S., Germany, France, and the U.K., as part of the International Working Group for Sabotage Concerns of Transport and Storage Casks (WGSTSC). WGSTSC partners need, and are helping coordinate this research and subsequent assessments, and to develop potential preventative measures for plausible sabotage events.

Sandia National Laboratories (SNL) Materials Transportation Testing and Analysis Department has the lead role for managing and performing this research program. Major support and expertise are provided by other SNL organizations including: Explosive Testing and Diagnostics, Plasma and Aerosol Processes, and Radiation Sciences/Nuclear Facilities and Technologies. Overall sabotage and transportation program support is provided by both the U.S. Department of Energy (DOE, Office of Civilian Radioactive Waste Management (OCRWM)/ RW Office of National Transportation) and the U.S. Nuclear Regulatory Commission (NRC, Offices of Research, and Nuclear Security and Incidence Response). Argonne National Laboratory (ANL), Energy Technology Division, has provided the detailed characterization and fabrication work for all spent fuel test rodlets to be used in this program. German participants, the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) and the Fraunhofer Institute of Toxicology and Experimental Medicine (ITEM), are providing supporting aerosol testing, expertise, and data analyses. The Institut de Radioprotection et de Surete Nucleaire (IRSN), France, has provided unirradiated depleted UO_2 (surrogate, DUO_2) fuel test rodlets for Phase 3 testing plus supporting modeling studies.

The purpose of this document is to focus on new developments and status of the overall test program and summarize the available aerosol data obtained over about the past year and one-half. The predominant aerosol-explosive testing during this period included six “Phase 2+” tests with surrogate cerium oxide pellets plus added (nonradioactive) fission product dopants in Zircaloy-4 rodlets, plus three “Phase 3” tests with unirradiated, DUO_2 rodlets, both with and without added fission product dopants. Description of previous test phase equipment, details, and available results were documented in earlier reports.[1,2,3]

DATA NEEDS

Aerosol particle testing requires sampling and quantification of the mass and physical characteristics of the aerosol particles produced from (spent fuel or surrogate rodlet) target-HEDD jet impact, with particle aerodynamic equivalent diameters (AED) up to 100 µm. For evaluations of aerosol and radiological consequences, there has always been a special emphasis on respirable particles, commonly defined as 0 to ~ 10 µm AED in size. Data from the coarser aerosol particles in the ~ 10 to 100 µm AED range, termed the non-respirable “inhalable” fraction, are of interest primarily for radiological “ground-shine” (dispersion, soil contamination, potential ingestion) consequence estimates.

This experimental program has been designed to quantify several important features of the interaction of a HEDD with spent fuel or surrogate material pellets contained within a “simplified” single Zircaloy-4 cladding tube/target rodlet. The source-term data measured includes:

1. The Respirable Fraction (RF). The RF of particles produced is defined as the mass of an element (i.e., U, Ce, Zr, Cs, etc.) in respirable particles (0 - 10 µm AED) / mass of that element in

the rod volume swept (particulated) by the HEDD. This RF, expressed as a percentage, is particularly relevant to the far-field (i.e., releases from a sabotage damaged spent fuel cask), airborne dispersion and consequence modeling studies.

2. The measurement of a more accurate and precise value for the Spent Fuel Ratio (SFR) for respirable particles. The SFR is defined as:

SFR = [Spent Fuel respirable particle masses] / ["Surrogate" DUO_2 respirable particle masses]

The SFR determination is, essentially, the comparison of the respirable, aerosol particle data from irradiated, spent fuel to the respirable, aerosol particle data from unirradiated, surrogate fuel. These data are obtained in paired experiments using the same apparatus, essentially identical test conditions, and using the same HEDD. For this experimental program, the RF, respirable particle masses for unirradiated "surrogate" DUO_2 target rodlets is being quantified with the Phase 3 tests, with preliminary results contained herein. The RF, respirable particle masses for irradiated spent fuel rodlets will be obtained with Phase 4 tests, scheduled to be performed in 2007. The measured SFR values will provide a data bridge to previous, large-scale surrogate (DUO_2) aerosol-explosive cask tests[4,5] performed in both the U.S. and Germany, and to consequence assessments. The SFR values permit scaling to other geometries, from a simplified single, short fuel rodlet, as tested, to rod bundles in casks, by means of supporting modeling studies.

3. The measurement of enhancement of volatile fission product nuclides like cesium and, to a lesser extent, ruthenium, preferentially sorbed onto specific, respirable particle size fractions in the sub-μm to μm size range. This enhanced sorption is expressed as an Enrichment Factor (EF), and can be integrated over the respirable particle size range. EF is defined as:

Enrichment Factor, EF = $RF_{(fission\ product\ element)}$ / $RF_{(uranium\ or\ cerium)}$

EXPERIMENTAL DESIGN and DETAILS

The overall spent fuel sabotage, explosive-aerosol measurement test program plan and design has been previously described in detail.[1,2,3] The major components for these tests include: test rodlets and target pellets (Zircaloy-4 cladding tubes, with ceramic pellets of cerium oxide (a chemical and ceramic surrogate for UO_2 fuel pellets), non-radioactive fission product dopants (external/adjacent to, or internal), un-irradiated depleted uranium oxide pellets, or actual spent fuel pellets -- within original, irradiated Zircaloy segments; plus support rods and hardware); a vertical, containment test chamber (approximately 0.6 m-diameter by 1.3 m-high, fabricated out of thick steel to contain the explosive blast and contain all aerosol particles produced) consisting of both an aerosol collection chamber and an explosive containment chamber; the HEDD, a conical shaped charge; aerosol particle samplers (particle impactors, sampling tubes, etc., described below); a HEDD-jet stop assembly; and, test facilities to perform the tests in. Test components and targets are specific to individual test phases; we will focus on the most recent tests.

These are primarily aerosol production and particle measurement/characterization experiments. We use 9-stage, multi-jet Marple cascade impactors (aerosol particle samplers), contained within four independent, redundant sampling assemblies per test. These impactors are designed to measure particle size distributions from about 0 to ~ 21 μm AED, plus an additional "pre-filter" stage for larger particles, ~21 to 35 μm AED. Aerosol sampling is conducted for a 10-second period following HEDD detonation. We also use separate, in-line, large-particle separators (LPS) for collecting the ~30-100 μm AED particles; the LPS collectors were jointly designed by SNL and Fraunhofer ITEM aerosol experts. Each Marple and LPS sampling assembly requires a vacuum

bottle and a critical orifice to draw a calibrated, nominal 2 L/min flow rate through the samplers; a small HEPA filter is also used, before the vacuum bottle. In earlier testing,[2] we used several other types of multistage aerosol particle samplers, including two Respicon™ 3-stage virtual particle impactors and a Berner 9-stage particle impactor, borrowed from Fraunhofer ITEM. The mass of all collected particles, on the impactor stages are first determined by weight gain measurements, then chemically dissolved; detailed chemical analyses of major elements and fission product species in the particles are obtained using inductively coupled plasma-mass spectrometry, ICP/MS. Chemical analyses are necessary because much of the collected particle mass consists of fine carbon soot, a combustion byproduct of the HEDD detonation.

The test plan[2,3] consists of sequential test phases, Phases 1 through Phase 4. Phase 1 tests, performed in 2001-2002, used glass targets as representative brittle materials, and focused on performance quantifications of the HEDD devices and refinement of the aerosol particle collection apparatus being used. The extensive Phase 2 test series,[1,2,3] performed in 2002-2004, used non-radioactive cerium oxide, CeO_2, in sintered ceramic pellets (nine per test), contained within short Zircaloy-4 cladding tube rodlets, similar to spent fuel rods. Pellet sizes (~7 mm-long x 9 mm diameter) and cladding tubing were sized to match H.B. Robinson PWR fuel rods.

During each test, the HEDD jet "particulates" approximately a 24-32 mm length of the target rodlet, leaving the end pellets and rodlet ends basically undamaged. Instrument measured conditions within the aerosol collection chamber include a temperature peak of ~900 K, dropping to ~400 K in 30 seconds, and a peak pressure of ~ 3 bar, dropping rapidly. Within the external aerosol sampling lines, measured peak temperature and pressures were only ~ +6 K and 1.5 bar, respectively.

Successive tests in Phase 2 allowed us to add and evaluate effects of multiple variables on target aerosolization response to HEDD jet impact, including: internal rodlet pressurization; different fission product dopant additions and form/distribution factors; several types of aerosol particle samplers; and, target rodlet materials (CeO_2 pellets of various lengths, surrogate high activity waste/high-level waste glass rodlets or pellets, contributed by our German test partners at GRS and Fraunhofer ITEM). All fission product dopant materials were totally aerosolized and possibly vaporized by the shock wave and thermal pulse from the action of the HEDD jet. During 2005, we added a supplemental Phase 2+ series of non-radioactive tests using fission product-doped surrogate cerium oxide pellets or doped German glass pellets, to evaluate the release and preferential sorption enhancement of cesium and other fission product dopants as a function of fission product distribution within or adjacent to the pellets. We used a new, partially vented aerosol collection chamber configuration (with the same volume as the vertical aerosol chamber used in other tests), with an external HEDD device, to also evaluate the effects of explosive byproduct carbon soot and chamber temperature rise from the HEDD detonation on the fission product EF. Aerosol results from the Phase 2+ tests are summarized in this report. Two upcoming tests in a vented German HEDD test setup with doped CeO_2 pellets will complete the Phase 2+ inter-comparison exercise.

There are six Phase 3 tests that use slightly radioactive, unirradiated depleted uranium oxide pellets in Zircaloy cladding tube test rodlets. The DUO_2 test rodlets were provided by our French test partner, IRSN. Each test rod contains five 13.8 mm-long pellets of ~ 95% theoretical density DUO_2, with dished ends. These tests incorporate the variables of internal rodlet pressurization (1 or 40 bar of He, similar to PWR fuel rods at the end of their life, within the end plenum regions of the rodlet), added non-radioactive fission product dopant disks (yes/no, surrounding the central DUO_2 pellet), and internal aerosol chamber atmosphere (either air on inert nitrogen). Phase 3 test-

ing began in 2005 and will be completed in 2006 (three of six tests completed to date). The Phase 3 tests use a self-containment, aerosol-explosive test chamber that is based on the similar, but less sophisticated Phase 2 test chamber design(s).[1,2,3] These slightly radioactive tests were performed at the SNL Explosive Components Facility, within a secondary containment housing, to prevent any radioactive particle release. Available aerosol results from the Phase 3 tests are also summarized herein.

Eight Phase 4 tests will use radioactive spent fuel pellets in their original irradiated Zircaloy cladding, from actual PWR spent fuel rods. These spent fuel pellets are being fabricated into short test rodlets, with a rodlet design similar to the Phase 3 DUO_2 rodlets.[1,2,3] Four of the Phase 4 tests will use a high-burnup spent fuel (~72 GWd/MTU) originating from the H.B. Robinson pressurized water reactor. The other four Phase 4 tests will use a low-medium burnup (~38 GWd/MTU) spent fuel originating from the Surry PWR. Two different burnup fuels are being tested because it is postulated that each may yield a different respirable fraction of particles, as a result of greater radiation damage in the higher-burnup fuel. All of the spent fuel has been characterized in detail and fabricated into test rodlets at Argonne National Laboratory (ANL), for SNL. The aerosol-explosive, vertical test chambers for Phase 4, spent fuel tests, are very similar to the Phase 2 and Phase 3 vertical explosive-aerosol test chamber. Once the remotely inserted spent fuel test rodlet has been explosively disrupted by the HEDD jet, the post-test chamber will not be opened, in order to prevent escape of highly radioactive particulates. The only particle sampling is via the four, redundant, top-mounted aerosol impactor sampling assemblies.

The Phase 4 explosive-aerosol tests will be performed at the SNL Gamma Irradiation Facility (GIF), Test Cell 3, starting in 2007, using closely controlled radiological and explosive safety conditions, under both SNL and DOE-Sandia Site Office (SSO) authorizations. The final measurement of the spent fuel ratio (SFR), calculated as a function of aerosol particle size ranges, will be obtained after the completion of Phase 4 tests.

AEROSOL DATA AND RESULTS

We have quantified the aerosol particle size distributions of all elemental species involved in the aerosol-explosive/sabotage process, including surrogate cerium or depleted uranium, copper (from the HEDD), zirconium (from the Zircaloy cladding tube), iron and aluminum (from test hardware), and cesium, strontium, ruthenium, and europium dopant fission product species present. The measured respirable fractions (RF) for surrogate Phase 2 cerium oxide and Phase 3 depleted uranium oxide pellet materials are summarized in Figure 1. For cerium oxide, the measured, average RF was 0.61 ± 0.25 %, based on the most recent Marple impactor data (our best quality and largest amount of interpretable data), with a 99% confidence interval. Similarly, using all measured data, including Marple (test 2/5E and newer) plus older Respicon and Berner impactor data (tests 2/1A through 2/5A), the average RF was 1.34 ± 0.56 %; note: results from these older tests[3] may have higher RF values due to use of different, partially vented square-box aerosol chambers.[2] The preliminary measured RF for DUO_2 is 1.31 ± 0.41 %, also with a 99% confidence interval, and is based on available data from the first two Phase 3 tests (tests 3/2 A and 3/5 B).

From observations of the Marple impactor cerium oxide distributions in the ~ 0 through ~20 µm AED size range, CeO_2 particles appear to peak broadly over the 3.5-9.8 µm respirable size range. No distinct CeO_2 particle size pattern is observed in the aerosol range from about 30 to 100 µm AED, collected with the LPS apparatus. The observed DUO_2 particle size distribution peaks quite strongly at about 3.5 µm AED, then decreases; in the aerosol size range, it is largest in the ~30-48 µm fraction, decreases, then starts to increase again above about 80 µm AED.

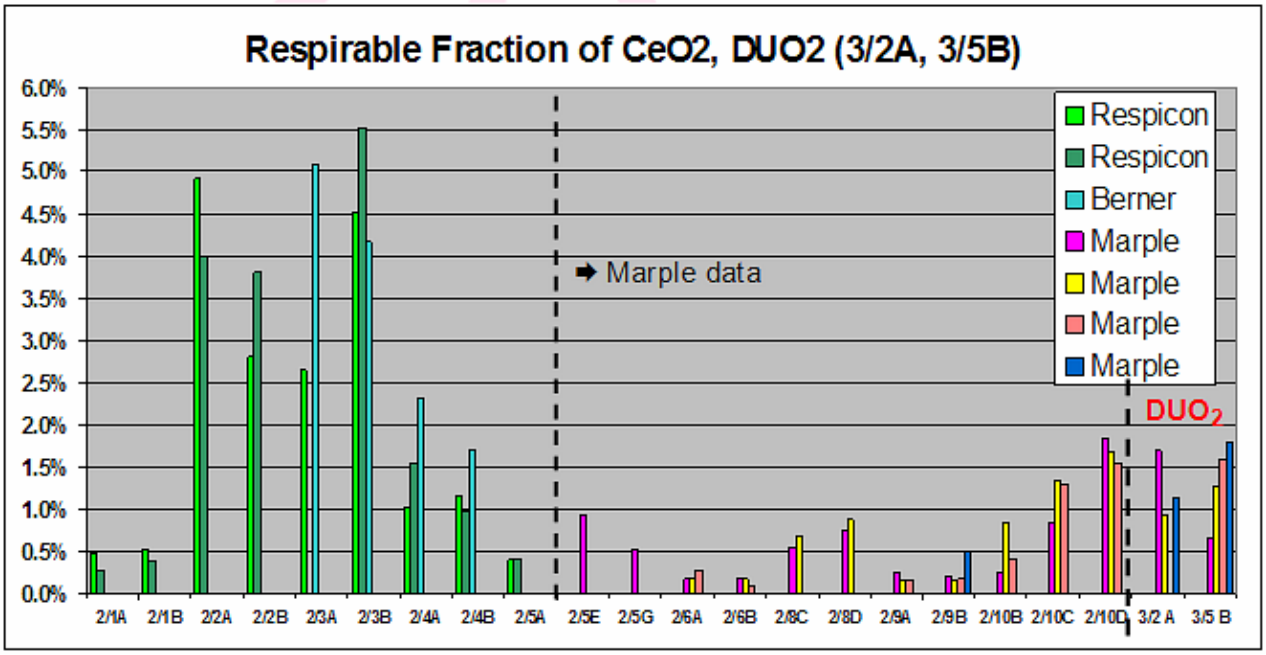

Figure Y. Measured Aerosol Respirable Fractions for Cerium Oxide and DUO_2 Pellets

Rodlet Pressurization Effects: Earlier CeO_2 aerosol-explosive tests[2] 2/6A and 2/6B were performed with internally pressurized rodlets, at 27.6 bar and 40 bar, respectively. Compared to tests 2/9A and 2/9B, performed[3] with un-pressurized (atmospheric pressure) rodlets in a similar vertical explosive-aerosol test chamber, no discernable effect of rodlet pressurization on measured RF can be noticed, as shown in Figure 1. Adding other test results to this comparison from other un-pressurized rodlets in tests[2] 2/5A, 2/5E, 2/5G, 2/8C and 2/8D, all performed in the identical test chamber as 2/6A and 2/6B, no specific effect of pressurization on RF can be obtained among the various tests. Similar results were obtained with the first two Phase 3 DUO_2 tests, test 3/2 (A) at atmospheric pressure and test 3/5 (B) with 40 bar of He within the rodlet; the measured DUO_2 RF for these two tests are essentially the same, regardless of pressure within. The conclusion is that the *internal pressurization effect in the plenum region of short* test rodlets (from 1 to 40 bars) is not a significant variable when compared to the total amount of particulates released from a relatively large (~27 mm) length of the rod impacted/particulated by the HEDD jet. The measured differences between results from multiple, replicate Marples impactors used on individual tests appear greater than the differences between un-pressurized and pressurized rodlet versions of several comparable tests.

Twelve tests with CeO_2 test rodlets, and one, so far, with DUO_2 test rodlets, have incorporated fission product dopants in several physical forms. All of the fission product dopant material in all test cases was within the HEDD jet particulated zone. The measured respirable fraction for cesium was significantly higher than that for CeO_2 or DUO_2 pellets. The observed cesium fission product dopant RF, illustrated in Figure 2, was 30 +/- 7.6% of dispersed mass based on Marple impactor data only, or 28 +/- 6% based on all data collected (with a 99% confidence interval). The observed particle size distribution for cesium has a distinct peak at 0.5-3.5 µm AED. The measured/calculated cesium fission product enrichment factor, EF, had a broad range of about 5 to 160, integrated over the respirable size range, dispersed particles, based on data obtained to date. The cesium EF, as a function of test condition, is still being interpreted.

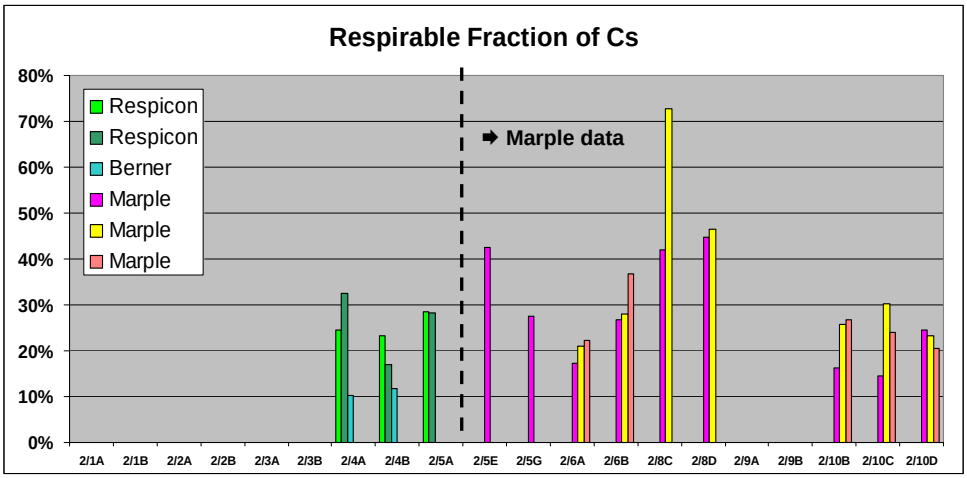

Figure 2. Cesium Fission Product Dopant Respirable Fraction

Aerosol data for volatile ruthenium fission product dopant has been measured to a limited extent, due to small quantities present in these tests. The average measured RF for ruthenium was 3.6 ± 1.7 % for all particle collectors, or 5.0 ± 2.2 % from the Marple impactors only, both at the 99% confidence interval. The preliminary EF for Ru ranged from <1 to 30+, and may be related to low detectability uncertainties. The measured RF for zirconium, from the Zircaloy-4 cladding, was 1.3 ± 0.3%. The Zr particles are produced both from HEDD jet impact and subsequent rapid oxidation (particle burning) that was observed (using high-speed photography) to occur within the first ~ 0.3 seconds after detonation.

DISCUSSION & SUMMARY

This test program, to quantify and characterize aerosol particles ***produced*** in a credible sabotage event on a spent fuel transport or storage cask, has been performed primarily at SNL since 2002. There has been major design input, participation, and supplemental testing from other U.S., German, French, and British partners, as part of the collaborative, International WGSTSC. This current "simplified single short-rodlet" testing portion of the overall program is designed to provide reliable, quantified source-term input data to parallel follow-on modeling efforts of near-field aerosol dispersion, computational fluid dynamics, and radiological consequence assessments. In addition, plans are in transition to perform joint-WGSTSC partner large-scale tests in Germany with multiple bundles of surrogate material rods in an actual cask-volume enclosure, with representative cask wall materials and a larger HEDD device, to measure the relative amount of aerosols ***released*** (internal distribution and amounts blown out) through the sabotage-produced hole in the "cask." Several modeling studies have been initiated, to tie these WGSTSC test programs and results, both previous[3,4,5] and future, together.

The predominant aerosol-explosive testing performed during about the last year at SNL consisted of the conduct of six new Phase 2+ tests, essentially completing surrogate, non-radioactive testing, plus the conduct of the first three Phase 3 tests using slightly radioactive, non-irradiated depleted uranium oxide pellet rodlets. The Phase 2+ tests were specifically added to the overall program to further evaluate the release and sorption enhancement of cesium, ruthenium, strontium, and europium fission product dopants as a function of several variables, as recommended by test partners in the International WGSTSC. The Phase 3 DUO_2 tests are required to determine the spent fuel ratio, along with results from the to-be-performed Phase 4 tests with actual spent fuel rodlets.

During this same time period, since the prior INMM review,[1] we have also analyzed and interpreted a large body of recently obtained aerosol particle data.

The average, measured respirable fractions for surrogate, Phase 2 CeO_2, is 0.61 ± 0.25 %, based on the most recent Marple impactor data, or 1.34 ± 0.56 %, based on older and new data, both with a 99% confidence interval. Similarly, the preliminary measured RF for Phase 3 DUO_2 is 1.31 ± 0.41 %. The CeO_2 and DUO_2 measured RF values are quite similar, as expected. There could be, however, appreciable particle loss in the aerosol sampling hardware lines from thermophoretic or diffusiophoretic deposition effects in these tests, with a measured high internal temperature, onto initially room-temperature test hardware. The extent of these deposition losses is still being quantified in laboratory calibrations. It is tentatively estimated that these effects might double the measured respirable fractions. Even so, these surrogate CeO_2 and DUO_2 RF values are appreciably below, but not inconsistent with, the 5% RF value for spent fuel used in an earlier Yucca Mountain Program analysis.[6] This suggests that the estimated respirable particle release predicted in that earlier analysis is likely to be somewhat conservative, i.e., the radiological consequences of a sabotage event on a spent fuel transport cask may not be as significant.

The measured high RF values for dopant fission product cesium, 30 +/- 7.6% of dispersed mass (Marple impactor data only), or 28 +/- 6% (based on all data collected, both with a 99% confidence interval), particle size distribution, and high integrated EF of about 5 to 160 are a clear indication that a significant amount of the cesium fission product species is both mechanically particulated *and* thermally volatilized. The CsI used as the dopant chemical melts at 899 K, 626 ºC, and boils at 1553 K, or undergoes a phase change during the explosive-aerosol process, then preferentially sorbs onto the other respirable size particles produced (of carbon soot-explosive residue, copper particles from the HEDD, and particles of surrogate fuel pellet). There were some observed differences in the measured cesium EF results between the physical forms of the dopant material used, whether located in external, non-homogeneous solid chemical wells in the pellets, or adjacent resin-based disks, or in a more nearly homogeneous distribution of these dopants within the CeO_2 pellets -- similar to the situation expected for fission products in actual spent fuel, irradiated UO_2 pellets. Recent cesium EF data from Phase 2+ tests with doped cerium oxide pellets and doped German HAW glass surrogate indicate lower EF values for Cs in the partially vented chamber with an external detonation of the HEDD compared to the closed test chamber with internal detonation (Phase 2 and 3 tests), with more carbon soot present and with higher chamber gas temperatures. These preliminary findings will be investigated further after results from the final two of Phase 2+ tests are available.

A large body of experimental aerosol data has been generated and analyzed to date, and a significant amount of additional dopant fission product and unirradiated DUO2 (Phase 3) and actual fission product and UO_2 spent fuel (Phase 4) data remains to be generated over the next year or so, to conclude this portion of the WGSTSC study. The Phase 3 DUO_2 tests were originally scheduled to be performed in the SNL GIF radiation facility[1,2,3] but were moved to the SNL Explosive Components Facility (ECF) during 2005, with a significant positive impact on test schedules. The ECF building had not been used previously for radioactive testing of this type or scope, so this move required: approved documentation of a NEPA amendment for the ECF; a Preliminary Hazard Screening/ Hazard Assessment review and approval; and, the need to include appropriate secondary containment of the test chamber within the ECF explosive blast chamber, to address potential release of particulate radioactive materials. These needs were satisfied; three DUO_2 explosive-

aerosol tests were successfully completed, to date. Negligible amounts of particulate contamination (at or below measurable levels) were released from the leak-tight test chamber during conduct and post- test sample retrieval, and during component decontamination procedures (prior to the subsequent test). Following completion of Phase 3 testing (during FY 2007), Phase 4 testing with actual spent fuel rodlets will move to the SNL GIF site. Final required safety basis authorization to use the SNL GIF facility for these tests is progressing forward. The SNL GIF Documented Safety Analysis 100% review document is scheduled to be approved by DOE Sandia Site Office, with the issuance of a final GIF Safety Evaluation Report (SER) before the end of 2006.

In conclusion, there are significant benefits and regulatory needs for the successful completion of this WGSTSC program for all participants involved. This program supports the U.S. DOE (including the Yucca Mountain repository transportation program) on international sabotage and security evaluations, and partner German, French, and British organizations to provide a measured basis for evaluating appropriate levels of physical protection, safeguards requirements, and preventative strategies for nuclear materials in use, transport, and storage. The experimental program provides reliable source-term data and analyses for a defensible validation of U.S. NRC vulnerability studies and follow-on computer modeling of aerosol dispersal hazards and radiological consequence assessments relevant to a credible sabotage attack. The measurement of the Spent Fuel Ratio allows scaling between simplified single rodlet results (as reported herein) and larger, cask-scale environments (with either surrogate or actual spent fuel materials). The continuing, successful conduct of this International WGSTSC cooperative program helps leverage test work and analyses across international organizations, and provides significant technical and policy benefits for all participants.

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